GRAIN SORGHUM RESPONSE TO TILLAGE AND CROP ROTATION

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ABSTRACT

Grain sorghum [Sorghum bicolor (L.) Moench] producers are challenged to utilize alternate production methods to slow rising production input costs and improve profitability. Objectives of this research include investigations of fossil fuel saving tillage practices, possible yield enhancing crop rotations and varying levels of fertilizer phosphorus (P) and micronutrients, iron (Fe) and zinc (Zn), on grain sorghum production. The influence of these cultural management practices on certain sorghum insects was also evaluated. The experimental site was a Clareville clay loam (hyperthermic, Pachic Argiustoll) located west of Robstown, TX at the Perry Foundation. Conventional tillage (7-8 tillage trips; 6-10" tillage depth) was compared with minimum tillage (3-4 trips; 3" maximum depth) under both continuous sorghum cropping and a sorghum: cotton (Gossypium hirsutum L.) yearly rotation. The major blocks, cropping systems, and sub-blocks, tillage systems were evaluated at three P fertilization rates. Micronutrients, Fe and Zn, were included at the high P rate in the minimum tilled (MT) treatment. Initial year results for sorghum following cotton compared to sorghum following sorghum showed a significant 30 percent grain yield increase when averaged across all tillage and fertilizer variables. With severe moisture stress in years 2 and 3, the rotation benefit decreased substantially due to drought stress. Phosphorus, Zn and Fe fertilizer response was measured in the third year. Early season plant growth differences in favor of MT failed to translated into final grain yield differences due to moisture stress prior to physiological maturity. Sorghum head insect count differences were largely changed by rotation in the three studies. Grain yields in Year 4 were considerably improved over yields for the past two years. While overall average yields were not significantly affected by treatment, yield breakout within tillage system shows up to 22% yield gain directly attributed to rotation with cotton. Yield response to P approached 28% under MT with sorghum following cotton with a lesser response in continuous sorghum. Sorghum head insect counts were not significantly changed by tillage or rotation alone but were affected by a rotation x tillage interaction in year 4 of the study. However, conclusive evidence of treatment effect on insects is not offered at this time without additional data collection. Preliminary economic evaluation of the positive benefits of reduced tillage, crop rotations and P indicate considerable impact by these variables. Summary of differences in input costs for power unit, equipment and labor allocation for sorghum production using the MT system in contrast to CT showed a savings for approximately $36.40 per acre. The 4-year average yield increase due to rotation was an impressive 21 percent. Assuming this yield increase translates into at least 525 lb grain/ac or some $15-$16 per acre additional net income, the additive benefits of using the MT system and crop rotation practices exceed $50 per acre.

INTRODUCTION

Improved crop yields and reduced production costs are vital to increased profitability in grain sorghum [Sorghum bicolor (L.) Moench] production in the South. Crop rotation and tillage management can have significant impact on soil quality parameters and subsequent crop yields.

Changes in both soil chemical and physical properties require many years to reach near equilibrium and, therefore, long-term studies are needed to properly evaluate the effects of rotation and changing tillage systems on soil quality. Reduction in tillage in the Southeast USA (Motta, et al., 2000) and the Southwest USA (Cripps and Matocha, 1987; Matocha, J.E. and D.R. Sorenson. 1987; Matocha, Provin and Vacek, 1999; Barber and Matocha, 1994) has been shown to improve soil chemical and physical quality parameters.

The objective of our research was to evaluate the influence of a cotton: sorghum rotation compared to continuous sorghum on grain head insects numbers and final grain yields under minimum (MT) and conventional tillage (CT) with varying P fertilization.

MATERIALS AND METHODS

Crop rotations included cotton and grain sorghum planted in alternating years compared with continuous sorghum. Tillage comparisons included a CT system involving 7-8 tillage operations per year that was compared with a MT system that reduced tillage operations to 3-4 per year. Tillage depths were restricted to 3 inches or less in MT and 6-10 inches in CT systems.

Soil fertility comparisons in all tillage and cropping systems were evaluated at three levels of P fertilizer; with the MT treatment supplemented with Zn and Fe. For Year 1, P rates were 0, 20, and 40 lb P_2O_5/ac, while in years 2, 3 and 4 rates were decreased to 0, 10, and 20 lb P_2O_5/ac. Nitrogen (N) was blanketed to all treatments except fertilizer control at soil test recommended rate for 5,500 lb/ac grain yield (approx. 60 lb N/Ac). All fertilizer was preplant, banded in a 4"x 3" matrix.

The experimental design was a randomized block design using crop rotation as main blocks, tillage treatments as sub-blocks, fertility levels as split-plots and plant densities as split-split plots. All treatments were studied in three replications.

The experiment was located in all years at the Perry Foundation farm west of Robstown, Texas on a Clareville sandy clay loam (Pachic Argiustoll). History of the experimental site included the field being split into commercial sorghum and cotton production with both crops receiving equal fertilizer N applications in previous seasons. Also, no P fertilizer had been applied for three seasons prior to the initial year of this study.

Other agronomic methodlogies involved in Year 1 included gaucho insecticide treated grain sorghum hybrid, DK-52 (medium maturity) which was planted on February 25, 2000, into seedbeds with marginal soil moisture. Seeding rate was 94,000 seed/ac in 30-inch rows. In years 2, 3 and 4 - the crop rotation, soil fertility, and tillage treatments were studied at two seeding densities (approximately 60,000 and 75,000 seed/ac). Both tillage systems and crop rotations were evaluated at reduced levels of P fertilizer (0, 10, 20, lb P_2O_5/ac) for each of the three seasons. Each split-split plot consisted of 6 rows with 250-foot row lengths.

Planter-box insecticide treated grain sorghum hybrid, DK-52 (medium maturity) was planted in all treatments in March, 2001 and 2002, into seedbeds with marginal soil moisture. In 2003, the same sorghum hybrid was seeded approximately four weeks late (April 10) due to wet fields. Appropriate statistical analyses were preformed on all collected field data.

Insect data were collected as follows. Tillage and crop rotation effects on abundance of soil inhabiting insects such as southern corn rootworm, grubs and borers were assessed in all years by visual inspection of early damage to sorghum plants. Later, three insect samples were taken from all treatments every other week over a 5-week period from May 17 to June 14, in the first three years. Samples were taken using the beat bucket method and consisted of 10 sorghum heads each. Insect data recorded included densities of headworm (*Helicoverpa zea*), rice stinkbug (*Oebalus pugnax*) and a total count of natural enemies, mainly predators. Most of the predators were ladybugs (*Scymnus* sp.), insidious flower bugs (*Orius insidiosis*), fire ants (*Solenopsis invicta*), green lacewings (*Chrysopa carnea*), damsel bugs (*Nabis* spp.), and spiders. Cocoons of one *Cotesia* parasitoid species were also observed. In 2003, insects were sampled from all sorghum plots 3 times, June 27, July 11, and July 27. Sampling methodlogy was identical to that described earlier.

RESULTS AND DISCUSSION

Grain Yields - Year 1:
Yield levels for the first year were considered satisfactory especially since only 5.9 inches of precipitation were recorded for the period following planting through physiological maturity. This represents approximately 60% of the long-term average. Grain yields ranged from a high of 3522 to a low of 2290 lb/ac. Average yield for all 24 treatments was 3007 lb/ac. Sorghum grown in rotation with cotton averaged 3384 lb/ac across tillage and fertility regimes while continuous sorghum produced average grain yields of 2605 lb/ac (Figure 1). This reflected a 30% increase in yield due specifically to crop rotation. The benefit from rotation appeared consistent within tillage systems and for most fertilizer rates. Yields remained largely unchanged due to tillage intensity. However, yield trends with continuous sorghum appeared lower for MT compared to CT at low P fertilizer rates. This effect was not evident when sorghum followed cotton. Additions of P fertilizer, in general, either with or without micronutrients Zn and Fe, had little effect on grain yields as expected since initial soil test values failed to indicate a need for P fertilizer.

Insect Evaluations - Year 1:
Damage to sorghum plants by soil inhabiting insects was monitored by visual inspection with no evidence of damage recorded for all years. Sorghum head insect counts were made at two dates. At the mid-May insect count, data indicated only small and largely non-significant differences in numbers of headworms and predators due to treatment. However, insect counts two weeks later, June 1, showed large increases in headworms, stink bugs and predators (Table 1). The headworm numbers were still below threshold levels, but stink bugs increased to an average range of 1.4 to 5.9 per head depending upon treatment variable and were above the economic threshold. Insecticide spraying for stink bugs was not required, however, because sorghum grain had just matured past the stage where stink bugs were no longer a yield affecting factor. Insect counts for the third period were not significantly affected by treatment.

Grain Yields - Year 2:
Grain yields for 2001 were drastically reduced by drought and approximated only 33 percent of expected normal yields. Only 3.61 inches of precipitation were recorded for the period following planting through physiological maturity. Grain yields ranged from a high of 2025 to a low of 1108 lb/ac. No yield difference was recorded due to plant density. Conventionally tilled sorghum grown in rotation with cotton yielded 1662 lb/ac when averaged over fertility regimes and population densities, while continuous sorghum produced average grain yields of 1373 lb/ac. or approximately 21% less (Figure 2). The benefit from rotation appeared less consistent and smaller within the MT system. Breakout of yields within the P rates showed larger rotation effects at lower P fertilizer rates.

Grain sorghum response to P fertilizer was variable with tillage intensity and cropping system. A statistically significant grain yield increase of 439 lb/ac was measured from 10 lb P_2O_5/ac in the CT and cotton: sorghum systems. Although variable, there appeared to be better response to rotation under CT as compared to the MT system as P fertilizer rates increased. As was the case in the initial year of this study, no yield improvement was recorded from Fe and Zn fertilization.

Grain yields remained largely unchanged due to tillage variables, although moisture readings down to 24-inch depths showed a positive influence from MT earlier in the growing season. However, abnormally high air temperatures and essentially no rainfall during critical stages of plant growth resulted in severe drought stress which masked the earlier substantial plant growth response from the MT system and prevented manifestation of increases in final grain yield.

Insect Evaluations - Year 2:
Damage to sorghum plants by soil inhabiting insects was monitored by visual inspection with no evidence of damage recorded as was the case in Year 1. Although tillage and fertilizer treatments had no effect on headworms, rotation did significantly affect headworm densities. During sampling periods 1 and 2, headworm densities were greater on sorghum planted in rotation with cotton (0.65 per plant), than for continuously planted sorghum (0.29 per plant). Rice stinkbugs were significantly affected only by an interaction between rotation, tillage, and fertilizer treatment. This interaction occurred because stink bug numbers were higher on the sorghum/cotton rotation than on continuous sorghum for the CT plots. This was also true for the MT system, but only when fertilizer treatments with Fe and/or Zn were excluded from the comparison. Rotation had no effect on stinkbug densities when Fe and/or Zn were added.

Grain Yields - Year 3:
Yields for 2002 were significantly improved over those for the 2001 season (2.23X) due to higher soil profile water at planting. Yields ranged from a high of 4276 to a low of 2241 lb/ac with both extremes measured with the higher plant density. Average yields for the 24 treatments were 3357 and 3231 for the high and low plant densities, respectively. Since data indicate that the small seeding rate variable (22%), had essentially no effect on grain yield, data is presented as averages over plant densities (Figure 3). Sorghum grown in rotation with cotton averaged 3312 lb/ac across treatment variables, while continuous sorghum produced average grain yields of 3073 lb/ac (n.s. difference). The average yield advantage in 2002 attributed specifically to rotation was 239 lb/ac that accounted for an 8% increase. However, further breakout of yields within tillage and plant density systems showed a 563 lb/ac increase due to rotation which reflected a 19% benefit at the higher plant populations.

Grain sorghum response to P fertilizer was variable with tillage intensity and cropping system. A yield increase of 510 lb/ac was measured from 20 lb P_2O_5/ac in the MT cotton: sorghum system. In general, response to P fertilization was less consistent as tillage intensity increased. Response to soil applied Zn and Fe together with 20 lb/ac of P_2O_5 was variable but appeared somewhat more consistent with continuous sorghum. Fluid Zn or Fe fertilizer mixed with the 11-37-0 (ammonium polyphosphate), applied individually, produced 1013 and 1140 lb/ac additional grain, respectively, when sorghum was grown without rotation at the lower plant population (Figure 4). This is the first such significant response measured and could be indicative of a developing nutritional requirement for micronutrients by grain sorghum under these conditions.

Reducing tillage to three operations rather than seven produced essentially no difference in grain yield as was the case in previous season, however soil moisture readings down to 24 inches showed a positive influence from MT earlier in the growing season**.**

Insect Evaluations - Year 3:
Sorghum midge populations definitely were not a yield limiting factor in the 2002 results. Headworms were only present during the first 2 sampling periods. None of the factors, rotation, tillage, or fertilizer treatment significantly affected headworm densities. In part this may have been due to very low densities with only 3.5 headworms per 10 heads during the first sampling period, 0.9 during the second period, and 0 during the 3rd period. Predators were also unaffected by any of the factors examined although their numbers were slightly higher than headworm numbers. Also, the relationship between headworm densities and predator densities was not statistically significant.

Rice stinkbug densities were significantly affected by both rotation and tillage (Table 2). Stinkbug densities were lower on sorghum grown in rotation with cotton (5.8 per 10 heads) than on continuous sorghum plots (8.9 per 10 heads) ($F=12.1$; $df=1, 9$; $p=0.042$). Tillage also significantly affected stinkbug densities, but only during the second sampling period, as demonstrated by the significant tillage by sampling date interaction ($F=7.3$; $df=2, 18$; $P=0.048$).

Grain Yields - Year 4:
Grain yield data are presented in Figures 5-7. Yields for 2003 increased to near long-term average yields and considerably above the yields measured in the first two years. Only 3.60 inches of precipitation were recorded for the period following planting through physiological maturity. This represents approximately 37% of the long-term average. However, substantial precipitation in months prior to planting provided a full profile of soil moisture. Grain yields ranged from a high of 4046 to a low of 2659 (lb/ac) lb/ac. Average yields for the 24 treatments were 3254 and 3219 (lb/ac) for the high and low plant densities, respectively, with no significant response to seeding rate regardless of tillage or cropping system. Sorghum grown in rotation with cotton averaged 3316 lb/ac across tillage, fertility regimes and population treatments, while continuous sorghum produced average grain yields of 3157 lb/ac. The benefit from rotation appeared consistent within tillage systems and for most fertilizer rates. These yields were greater than last season's drought stressed production, but the overall average yield advantage attributed specifically to rotation was nonsignificant. However, further breakout of the yield data within the minimum till systems showed a range of 8 to 19% yield increase from rotation at the lower plant population. Sorghum grown under CT produced yield increases of 14 to 22% attributed to crop rotation. As P fertilizer rates increased, there appeared to be better response to rotation under both MT and the CT systems. Response to P fertilizer was measured under both tillage systems but the largest yield increase occurred with MT. Twenty lb/ac of P_2O_5 applied to sorghum following cotton increased grain yields 850 lb/ac or some 28%. The addition of trace elements, Zn, and Fe, to continuously cropped sorghum produced a slight yield increase, with the largest yield boost was recorded when the two trace elements were supplied in combination (Figure 6). Yield data shows that trace elements were not required by sorghum grown in rotation with cotton. However in a monoculture sorghum system, Zn influenced yields only when chelated Fe was applied.

Headworm densities were low every week, with 0.71 per head during week 1, 0.094 during week 2, and 0.005 during week 3. Due to the very low numbers during weeks 2 and 3, only significant factor effects were tested during week 1. During week 1, mean headworm densities were not significantly affected by fertilizer treatment. Also, headworm densities were not significantly affected by either rotation or tillage alone, but were affected by a rotation by tillage interaction. This occurred because mean headworm density was lower in MT plots in continuous sorghum (0.46 per head) than in MT plots in the sorghum/cotton rotation (0.92 per head). However, mean headworm densities were not significantly different in the CT system in continuous sorghum (0.79 per head) than with CT in the sorghum/cotton rotation (0.71 per head).

Mean rice stinkbug densities increased from week 1 (0.3 per head), to week 2 (0.44 per head) to the highest level during week 3 (0.51 per head), but were not significantly affected by rotation, tillage, or fertilizer treatments. Similarly, treatments did not affect overall predator density.

SUMMARY

Economic Impact:
Preliminary economic evaluations of the positive benefits of reduced tillage, crop rotations and P fertilization indicate considerable impact by these variables, some more than others, on the profitability of grain sorghum production under dryland conditions in South Texas.

Summary of differences in input costs for power unit, equipment and labor allocation for sorghum production using the MT system in contrast to CT showed a savings of approximately $36.40 per acre. These savings coupled with a slight increase in grain yields (approximately 210 lb/ac, 4-year mean) due to reduced tillage pushes the per acre savings to over $40/acre.

In addition to the tillage variable impact on per acre costs of grain sorghum production, this PROFIT project had begun to demonstrate the additional yield benefits due exclusively to rotating sorghum with cotton in a one year system. The 4-year average yield increase was an impressive 21 percent. Assuming the 21 percent yield increase translated into at least 525 lb grain/ac or some $15-$16 per acre additional net income, the additive benefits of using reduced tillage and crop rotation practices exceed $50 per acre**.** Due to recent budget constraints, unfortunately this project had to be terminated before the full benefits of MT and crop rotation are realized.

ACKNOWLEDGEMENTS

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Table 1. Mean numbers of sorghum head insects & predators for fertilizer, tillage and cropping systems variables (PROFIT-00).

Systems			May 17, avg. of 10 head			June 1, avg. of 10 heads		
Cropping	Tillage	[1]Fertility (lb/Ac)	Head worms	Stink bugs	Predators	Head worms	Stink bugs	Predators
Sorg:Sorg	[2]CT	P = 0	0.17	0.03	0.00	0.57	1.40	0.43
Cot:Sorg	CT	P = 0	0.17	0.21	0.07	0.23	4.73	0.10
Sorg:Sorg	[3]MT	P = 0	0.27	0.57	0.03	0.53	1.70	0.33
Cot:Sorg	MT	P = 0	0.17	0.53	0.00	0.27	4.97	0.50
Sorg:Sorg	CT	P = 20	0.20	0.03	0.13	0.77	2.13	0.20
Cot:Sorg	CT	P = 20	0.20	0.43	0.03	0.27	3.57	0.10
Sorg:Sorg	MT	P = 20	0.23	0.03	0.03	0.50	2.03	0.33
Cot:Sorg	MT	P = 20	0.23	0.67	0.00	0.10	5.90	0.23
Sorg:Sorg	CT	P = 40	0.07	0.07	0.40	0.70	3.27	0.13
Cot:Sorg	CT	P = 40	0.20	.013	0.07	0.23	3.97	0.17
Sorg:Sorg	MT	P = 40	0.00	0.03	0.00	0.63	1.50	0.47
Cot:Sorg	MT	P = 40	0.07	0.77	0.03	0.17	5.60	0.13
Sorg:Sorg	MT	P = 40 + Zn	0.13	0.47	0.00	0.47	2.13	0.43
Cot:Sorg	MT	P = 40 + Zn	0.17	1.67	0.03	0.23	4.83	0.23
Sorg:Sorg	MT	P = 40 + Fe	0.17	0.43	0.03	0.57	1.63	0.23
Cot:Sorg	MT	P = 40 + Fe	0.13	0.23	0.00	0.67	4.60	0.27
Sorg:Sorg	MT	P = 40 + Zn + Fe	0.13	0.03	0.03	0.53	2.60	0.30
Cot:Sorg	MT	P = 40 + Zn + Fe	0.20	0.50	0.07	0.20	4.43	0.33

[1]N fertilizer blanketed to all treatments except fertilizer control. P rates are expressed as lb/ac of P_2O_5. Fe & Zn both applied preplant in band with N & P.
[2]CT=Conventional tillage.
[3]MT=Minimum tillage. Fertility P had no effect on all 3 insects.

Table 2. Mean numbers of rice stinkbug per 10 sorghum plants for different fertilizer, tillage treatments in sorghum: cotton rotation or continuous sorghum plots (Sorghum PROFIT - 2002).

Fertilizer Treatments	Conventional Tillage				Reduced Tillage			
	Sorg:Cott	S.E.	Sorg:Sorg	S.E.	Sorg:Cott	S.E.	Sorg:Sorg	S.E.
N0P0	3.67	0.87	7.56	2.56	5.67	0.60	9.00	
P0	5.78	1.87	12.56	2.80	5.89	0.61	8.00	
P20	5.00	1.55	8.89	1.89	8.11	1.54	9.00	
P40	9.56	4.41	8.00	2.13	4.89	1.81	7.00	
Combined	6.00	1.28	9.25	1.18	6.14	0.64	8.25	
P40Fe	NA		NA		5.22	0.95	12.56	
P40Zn	NA		NA		4.44	0.78	9.11	
P40FeZn	NA		NA		5.11	1.49	5.44	
Combined					4.92	0.97	9.04	

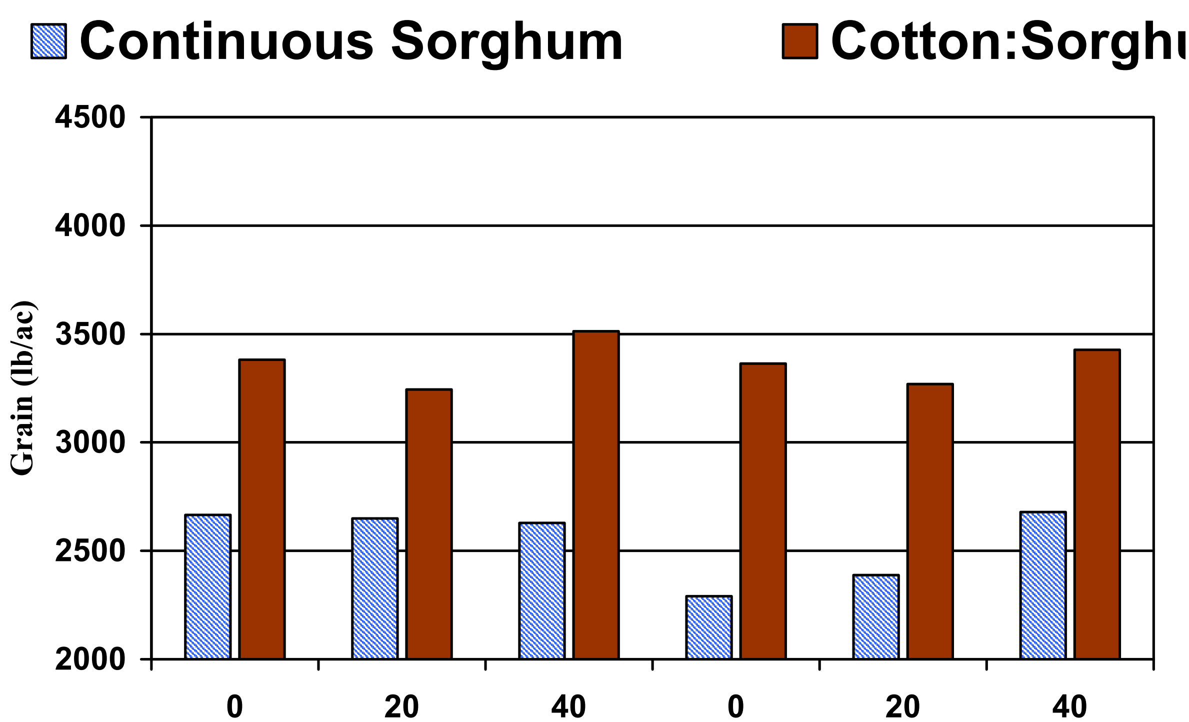

Figure 1. Effects of P fertilization and crop rotation on grain sorghum grown under conventional and minimal till systems (Sorghum PROFIT - 00). LSD (0.05) = 554.

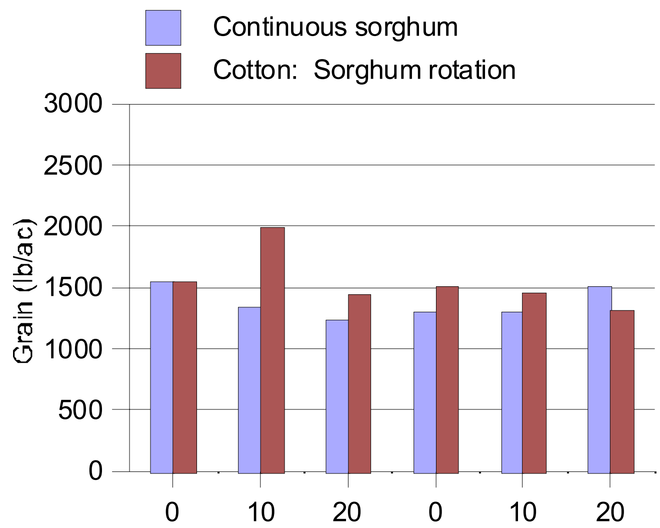

Figure 2. Effects of P fertilization and crop rotation on grain sorghum grown under conventional and minimum till systems, averaged over plant populations (Sorghum PROFIT-01). LSD (0.05) = 429.

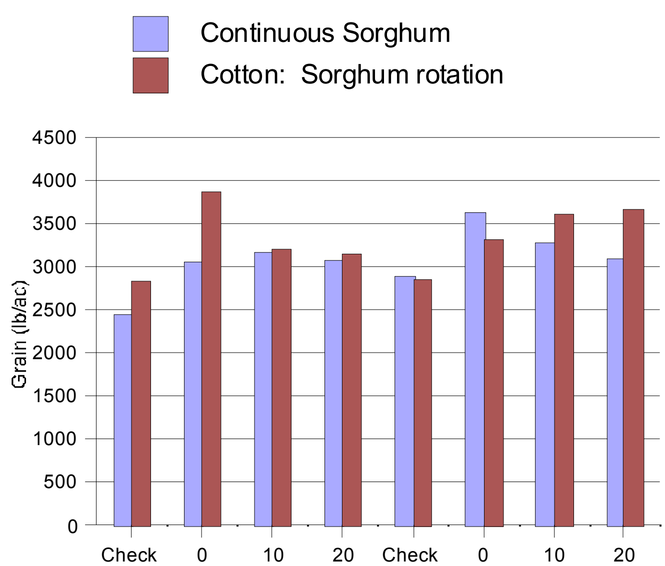

Figure 3. Effects of P fertilization and crop rotation on grain sorghum grown under conventional and minimum till systems, average over plant densities. (Sorghum PROFIT - 02). LSD (0.05) = 1064.

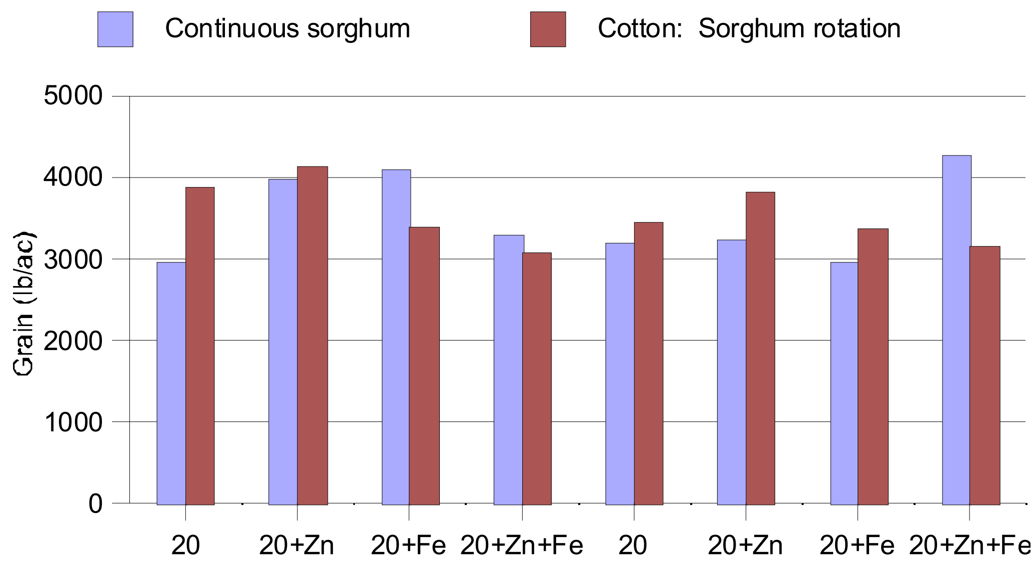

Figure 4. Effects of P, Zn, Fe fertilization and crop rotation on grain sorghum grown under minimum till at two plant populations (Sorghum PROFIT-02). LSD (0.05) = 1064.

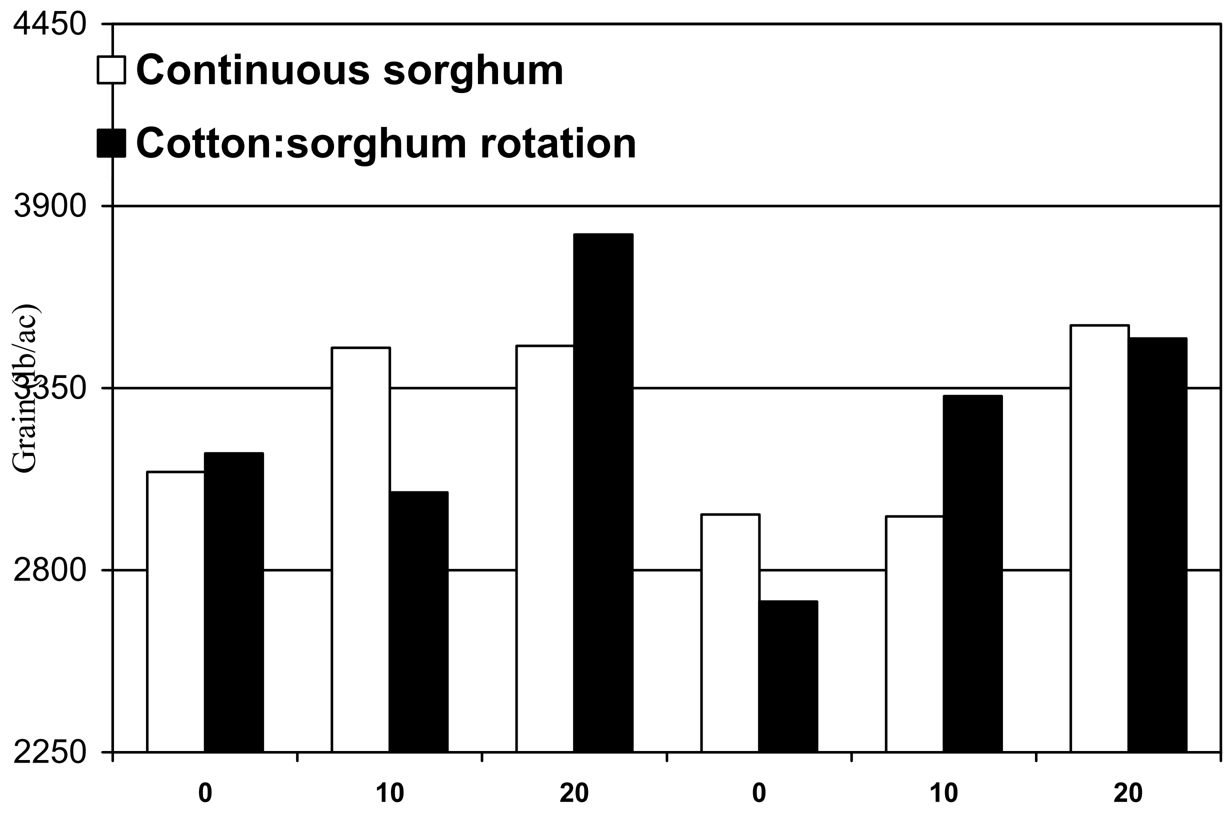

Figure 5. Effects of P fertilization and crop rotation on grain sorghum grown under conventional and minimum till systems at higher plant populations (Sorghum PROFIT - 03). LSD (0.05) = 638.

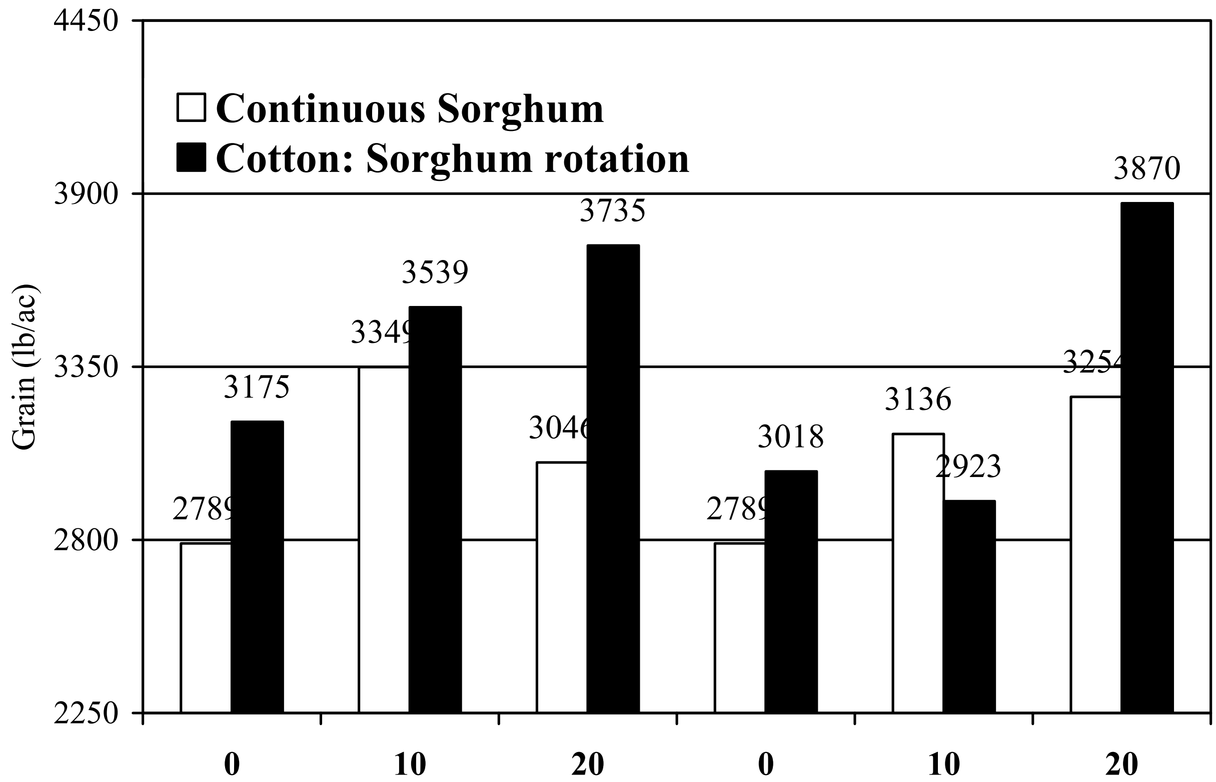

Figure 6. Effects of P fertilization and crop rotation on grain sorghum grown under conventional and minimum till systems at lower plant populations (Sorghum PROFIT - 03). LSD (0.05) = 801

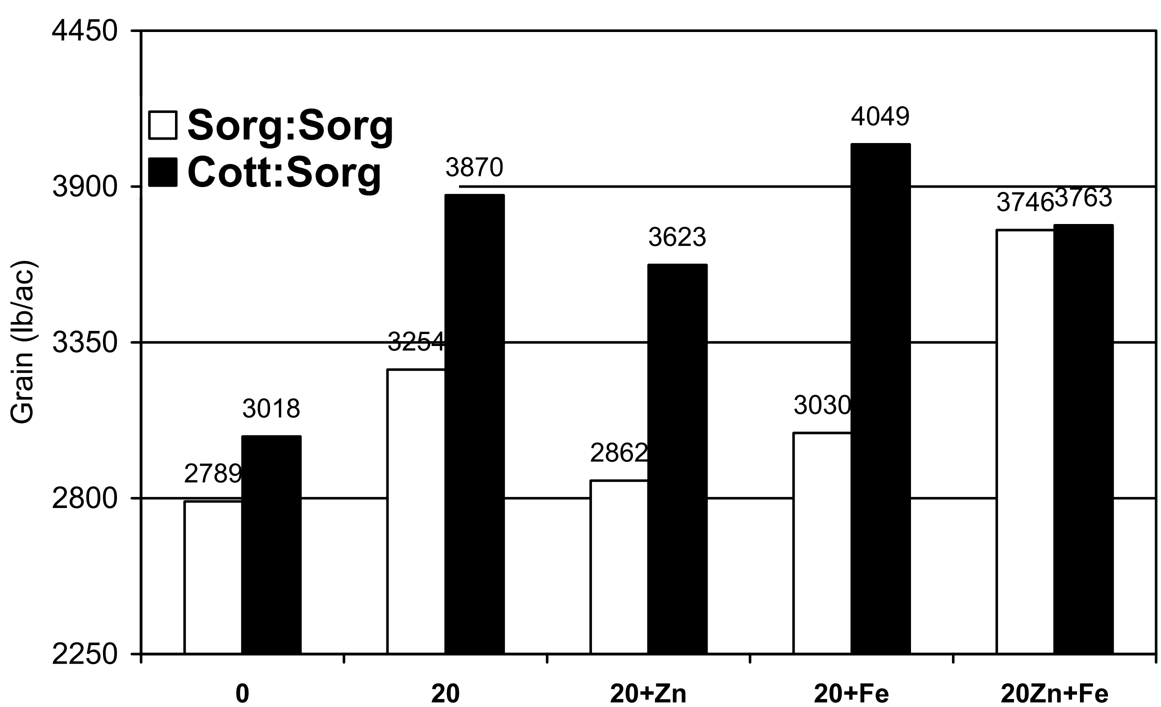

Figure 7. Response to P and trace element fertilizers by grain sorghum grown under rotation, minimum tillage and lower plant population (Sorghum PROFIT - 03). LSD (0.05) = 802.